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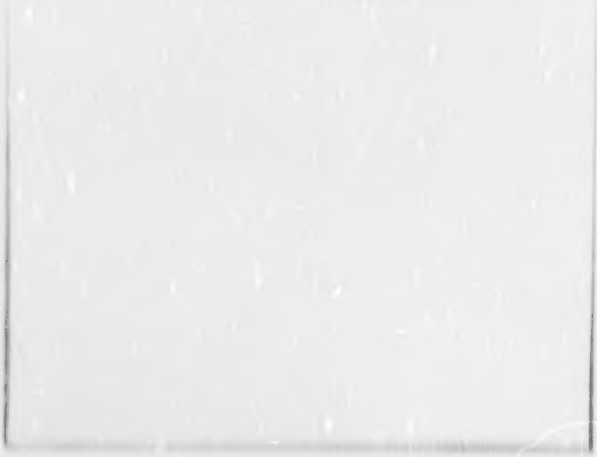

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REPORT
ON
WHITNEY RESERVOIR
BOSQUE AND HILL COUNTIES
TEXAS
EPA REGION VI
WORKING PAPER NO. 668

WITH THE COOPERATION OF THE
TEXAS WATER QUALITY BOARD
AND THE
TEXAS NATIONAL GUARD
MARCH 1977

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

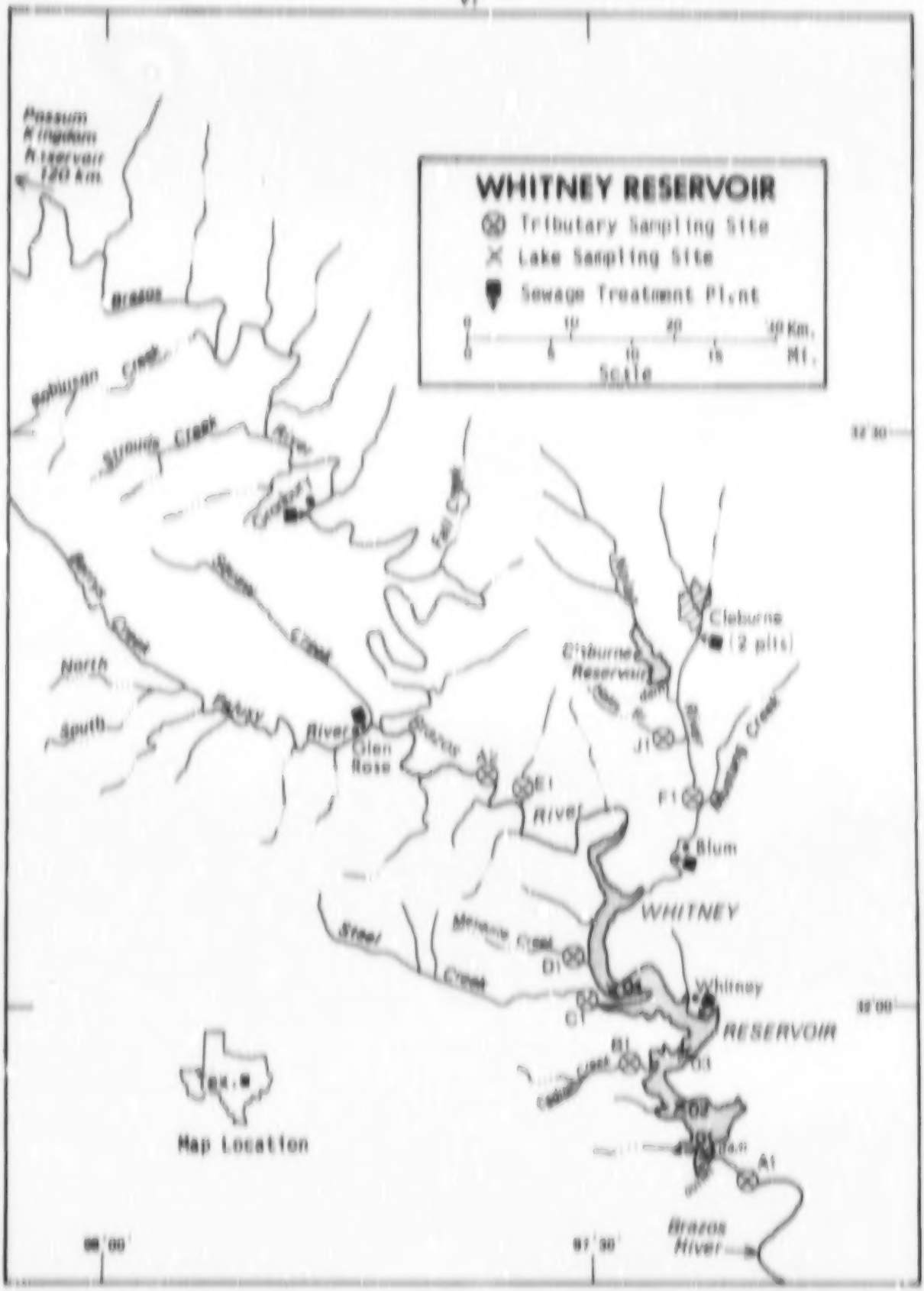
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


WHITNEY RESERVOIR
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Plant
Scale
Possum Kingdom Reservoir 120 Km.
Brazos
Bebuljan Creek
Stroud Creek
North
South
Bosque River
Glen Rose
Cleburne (2 pits)
Cleburne Reservoir
Blum
WHITNEY
RESERVOIR
Whitney
Brazos River
Map Location
Tex.
97°30'

WHITNEY RESERVOIR

STORET NO. 4839

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Whitney Reservoir is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the reservoir. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Whitney Reservoir ranked fifteenth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six water quality parameters*. Fourteen of the reservoirs had less median total phosphorus, eight had less and two had the same median dissolved orthophosphorus, 18 had less and one had the same median inorganic nitrogen, 11 had less mean chlorophyll a, and eight had greater mean Secchi disc transparency. Marked depression or depletion of hypolimnetic dissolved oxygen occurred at all sampling stations in May and August.

Survey limnologists noted submerged vegetation in the shallows near stations 1 and 2 in August. Reportedly, aquatic vegetation is not a problem in this reservoir, however (Anonymous, 1973).

* See Appendix A.

B. Rate-Limiting Nutrient:

The algal assay results are not considered representative of conditions in the reservoir at the time of sampling due to significant nutrient changes in the sample during shipment from the field to the laboratory. The reservoir data indicate phosphorus limitation at all stations in March and May but nitrogen limitation at all but station 1 in November.

C. Nutrient Controllability:

1. Point sources--During the sampling year, point sources contributed 9.7% of the total phosphorus load to Whitney Reservoir. The wastewater treatment plants at Cleburne contributed an estimated 5.6%, the facility at Granbury contributed an estimated 2.2%, and three other facilities, along with septic tanks serving shoreline dwellings, collectively contributed an estimated 1.9%.

The present phosphorus loading of 1.24 g/m^2/year is 1.9 times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 16), but even complete removal of phosphorus at the listed point sources would leave a loading of 1.12 $g/m^2/yr$. However, regardless of the applicability of Vollenweider's eutrophic level to Texas water bodies, Whitney Reservoir is phosphorus-limited much of the time, and point source phosphorus control could help slow the rate of eutrophication, particularly if a significant portion of the phosphorus export of the Nolan River proves to be controllable (see below).

2. Non-point sources--It is estimated that the phosphorus contribution of non-point sources accounted for 90.3% of the total load impacting Whitney Reservoir. The Brazos River contributed 56.2%, Nolan River contributed 31.2%, and two other gaged tributaries collectively contributed 0.6%. Ungaged minor tributaries and immediate drainage were estimated to have contributed 1.0%.

The phosphorus export rate of Nolan River was from 20 to 40 times greater than the rates of the other reservoir tributaries (see page 15). This is indicative of an underestimation of the contribution of the wastewater treatment plants at Cleburne.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 95.35 kilometers².
2. Mean depth: 8.1 meters.
3. Maximum depth: >30.2 meters.
4. Volume: 773.619 x 10^6 m^3.
5. Mean hydraulic retention time: 0.8 years (based on 1972-1976 mean outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Brazos River	66,824.8	42.170
Cedron Creek	108.8	0.466
Steel Creek	233.1	0.920
Nolan River	909.1	2.870
Minor tributaries & immediate drainage -	609.0	2.350
Totals	67,684.8	48.776

2. Outlet -

Brazos River	67,780.2**	46.890

C. Precipitation***:

1. Year of sampling: 91.4 centimeters.
2. Mean annual: 87.6 centimeters.

† Table of metric conversions--Appendix B.
†† At conservation pool; Barrows, 1977.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Whitney Reservoir was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at four stations on the reservoir (see map, page vi). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 30.2 meters at station 1, 22.3 meters at station 2, 21.9 meters at station 3, and 12.8 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table (the August nutrient samples were not preserved properly and were not analyzed).

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS AT [illegible] LAKE
STREET [illegible]

PARAMETER	1ST SAMPLING ([illegible])			2ND SAMPLING ([illegible])			3RD SAMPLING ([illegible])		
	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
TEMP (C)	15.5 - 17.0	16.3	16.3	20.9 - 25.1	23.7	23.5	24.2 - 25.1	25.0	25.1
DISS OXY (MG/L)	6.8 - 12.9	9.1	9.3	1.8 - 7.6	4.5	3.0	6.8 - 7.5	7.2	7.0
CONDUCTIVITY (MICROMHOS)	1478. - 1878.	1567.	1515.	1868. - 2084.	1966.	1963.	1478. - 2023.	1855.	1834.
PH (STAND UNITS)	7.8 - 8.3	8.1	8.2	7.4 - 8.3	7.8	7.7	7.5 - 8.1	8.0	8.0
TOT ALK (MG/L)	124. - 144.	131.	129.	122. - 155.	133.	125.	[illegible]	[illegible]	[illegible]
TOT P (MG/L)	0.019 - 0.035	0.025	0.021	0.013 - 0.132	0.029	0.017	[illegible]	[illegible]	[illegible]
DISS P (MG/L)	0.004 - 0.004	0.005	0.005	0.004 - 0.031	0.008	0.004	[illegible]	[illegible]	[illegible]
NO2+NO3 (MG/L)	0.262 - 0.298	0.274	0.268	0.023 - 0.298	0.094	0.068	[illegible]	[illegible]	[illegible]
AMMONIA (MG/L)	0.021 - 0.228	0.055	0.042	0.028 - 0.248	0.069	0.036	[illegible]	[illegible]	[illegible]
KJEL N (MG/L)	0.488 - 0.788	0.648	0.605	0.388 - 1.089	0.526	0.588	[illegible]	[illegible]	[illegible]
INORG N (MG/L)	0.350 - 0.388	0.338	0.335	0.048 - 0.360	0.197	0.178	[illegible]	[illegible]	[illegible]
TOTAL N (MG/L)	0.463 - 0.788	0.554	0.488	0.248 - 1.089	0.625	0.588	[illegible]	[illegible]	[illegible]
CHLOPYL A (UG/L)	3.7 - 4.3	2.6	3.9	1.5 - 5.8	3.2	2.7	23.9 - 38.8	34.9	34.5
SECCHI (METERS)	1.3 - 2.7	2.1	2.4	0.7 - 2.7	1.7	1.8	1.1 - 1.8	1.6	1.7

A SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR WHITNEY LAKE
STORET CODE 4639

 SAMPLING [illegible] 1/74)

PARAMETER	4 SITES RANGE	MEAN	MEDIAN
TEMP (C)	20.0 - 22.3	21.0	22.0
DISS OXY (MG/L)	2.6 - 7.6	5.4	7.2
CNDCTVY (MICROMO	1662. - 2486.	1984.	1953.
PH (STAND UNITS)	7.3 - 8.1	7.6	7.6
TOT ALK (MG/L)	88. - 111.	102.	104.
TOT P (MG/L)	0.029 - 0.053	0.041	0.040
DFTHO P (MG/L)	0.007 - 0.032	0.017	0.016
NO2+NO3 (MG/L)	0.019 - 0.050	0.034	0.030
AMMONIA (MG/L)	0.040 - 0.330	0.134	0.075
KJEL N (MG/L)	0.500 - 0.800	0.650	0.600
INORG N (MG/L)	0.060 - 0.390	0.170	0.105
TOTAL N (MG/L)	0.520 - 0.800	0.695	0.635
CHLRPHL A (UG/L)	4.0 - 15.0	7.0	6.3
SECCHI (METERS)	0.6 - 2.2	1.6	1.4

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/06/74	1. Scenedesmus sp.	804
	2. Oocystis sp.	686
	3. Chroomonas sp.	356
	4. Cricigenia sp.	237
	5. Ankistrodesmus sp.	165
	Other genera	383
	Total	2,651
05/16/74	1. Scenedesmus sp.	382
	2. Tetraedron sp.	127
	3. Coelastrum sp.	32
	4. Oscillatoria sp.	32
	5. Euglena sp.	32
	Other genera	80
	Total	685
08/13/74	1. Oscillatoria sp.	2,265
	2. Lyngbya sp.	1,762
	3. Anabaenopsis sp.	1,611
	4. Diploneis sp.	1,007
	5. Pennate diatoms	705
	Other genera	2,266
	Total	9,616
11/01-04/74	1. Dactylococcopsis sp.	1,261
	2. Oocystis sp.	850
	3. Oscillatoria sp.	521
	4. Merismopedia sp.	274
	5. Tetraedron sp.	274
	Other genera	576
	Total	3,756

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
03/08/74	1	1.7
	2	2.0
	3	1.9
	4	4.3
05/16/74	1	1.6
	2	2.4
	3	3.0
	4	5.8
08/13/74	1	11.9
	2	14.4
	3	14.6
	4	18.8
11/01-04/74	1	4.8
	2	7.2
	3	5.4
	4	10.8

C. Limiting Nutrient Study:

Due to significant nutrient changes in the samples during shipment from the field to the laboratory, the algal assays are not considered representative of conditions in the reservoir at sampling time. The reservoir data indicate that phosphorus was the limiting nutrient in March and May; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 10/1 or greater at all stations. However, nitrogen limitation is indicated in November at stations 2, 3, and 4 (nearest the point sources), and phosphorus limitation is indicated at station 1; i.e., the mean

inorganic nitrogen/orthophosphorus ratios were 12/1 or less at stations 2, 3, and 4 and 15/1 at station 1.

Nitrogen limitation, as indicated by in-lake nitrogen to phosphorus ratios, does not necessarily mean that the trophic condition of the lake can be improved by controlling nitrogen inputs. In many cases, the apparent condition of nitrogen-limitation results from excessive phosphorus input from point sources and is often accompanied by a corresponding increase in primary production. In such cases, the reversal of the enriched condition depends upon phosphorus control, not nitrogen control.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads at stations B-1 and C-1, in kg/km^2/year, and multiplying the means by the ZZ area in km^2.

The operators of the Cleburne, Granbury, Glen Rose, Blum, and Whitney wastewater treatment plants did not participate in the Survey; nutrient loads from these sources were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m^3/capita/day.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Cleburne (2 plants)	5,800	tr. filter	2,195.3	Buffalo Creek/ Nolan River
Granbury	2,300	tr. filter	870.6	Brazos River
Glen Rose	400	stab. pond	151.4	Paluxy River
Blum	450	act. sludge	170.3	Nolan River
Whitney	900	stab. pond	340.6	Whitney Reservoir

2. Known industrial - None

* Anonymous, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Brazos River	66,235	56.2
Cedron Creek	216	0.2
Steel Creek	380	0.3
Nolan River	36,740	31.2
b. Minor tributaries & immediate drainage (non-point load) -	1,220	1.0
c. Known municipal STP's -		
Cleburne	6,575	5.6
Granbury	2,610	2.2
Glen Rose	455	0.4
Blum	510	0.4
Whitney	1,020	0.9
d. Septic tanks* -	240	0.2
e. Known industrial - None	-	-
f. Direct precipitation** -	1,670	1.4
Total	117,980	100.0

2. Outputs -

Lake outlet - Brazos River 28,815

3. Net annual P accumulation - 89,065 kg.

* Estimate based on 8 campgrounds, 8 parks, and 805 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/ yr	% of total
a. Tributaries (non-point load) -		
Brazos River	1,260,695	75.6
Cedron Creek	10,360	0.6
Steel Creek	23,380	1.4
Nolan River	167,785	10.1
b. Minor tributaries & immediate drainage (non-point load) -	59,380	3.6
c. Known municipal STP's -		
Cleburne	19,725	1.2
Granbury	7,820	0.5
Glen Rose	1,360	<0.1
Blum	1,530	0.1
Whitney	3,060	0.2
d. Septic tanks* -	9,425	0.5
e. Known industrial - None	-	-
f. Direct precipitation** -	102,940	6.2
Total	1,667,460	100.0

2. Outputs -

Lake outlet - Brazos River 1,395,635

3. Net annual N accumulation - 271,825 kg.

* Estimate based on 8 campgrounds, 8 parks, and 805 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Brazos Creek	1	19
Cedron Creek	4	95
Steel Creek	5	100
Nolan River	40	185

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Mesquite Creek	0.020	0.715
Camp Creek	0.022	0.767
Haley Branch	0.169	1.213

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	1.24	0.93	17.5	2.9

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Whitney Reservoir:

"Dangerous" (eutrophic loading)	0.64
"Permissible" (oligotrophic loading)	0.32

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG C	[illegible] [illegible] SEC	[illegible] CHLPHA	[illegible] [illegible] AS	[illegible] [illegible] DATAS P
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	LAKE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible] CITY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	EAGLE [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	FT [illegible] [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LITTLE [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE OF THE PINES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	PALESTINE LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	SAN [illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	SAN [illegible] RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	E + SPENCE RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LAKE Data TO BE USED In Agreement

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INDEX N	[illegible] MEAN SEC	[illegible] CHLOR	[illegible] NO. 10	[illegible] CHLOR (mg/m³) P
[illegible]	SOMERVILLE LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	STAMFORD LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	STILLHOUSE HOLLOW RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	TAWAKONI LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	TEXARKANA LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	TEXOMA LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	TRAVIS LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	TROPICANA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	TWIN BUTTES RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	WHITE ROCK RESERVOIR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	WHITNEY LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] 8 LAKES WITH [illegible] VALUES [illegible] NUMBER OF LAKES WITH [illegible] VALUES

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	[illegible] SEC	[illegible] CHLOR	[illegible]	[illegible]	[illegible]
401	[illegible] LAKE	95 (36)	5 (2)	108 (38)	108 (26)	39 (14)	63 (23)	40
402	[illegible] LAKE	79 (30)	74 (28)	82 (31)	47 (18)	17 (6)	92 (34)	34
403	[illegible] RESERVOIR	92 (35)	6 (18)	97 (37)	68 (26)	17 (6)	84 (32)	38
404	[illegible] LAKE	5 (2)	42 (16)	58 (19)	4 (3)	48 (17)	5 (2)	15
405	[illegible] LAKE	66 (25)	78 (29)	29 (11)	87 (33)	58 (22)	94 (35)	34
406	LAKE [illegible]	47 (18)	21 (7)	74 (28)	63 (24)	17 (6)	34 (14)	26
407	[illegible] LAKE	26 (10)	91 (33)	42 (16)	32 (12)	76 (29)	38 (18)	24
408	[illegible] LAKE	45 (17)	108 (38)	47 (18)	11 (4)	67 (25)	92 (34)	36
409	[illegible] RESERVOIR	66 (25)	8 (3)	95 (36)	47 (17)	48 (17)	97 (37)	44
410	LAKE [illegible] CITY	39 (14)	76 (28)	26 (10)	42 (16)	88 (32)	35 (14)	31
411	[illegible] CREEK LAKE	8 (3)	47 (18)	18 (7)	13 (5)	61 (23)	8 (3)	19
412	[illegible] LAKE	68 (26)	83 (31)	32 (12)	29 (11)	97 (37)	63 (23)	37
413	EAGLE [illegible] LAKE	71 (27)	91 (33)	34 (13)	79 (30)	79 (30)	76 (28)	43
414	FT [illegible] HILL LAKE	24 (9)	66 (25)	21 (8)	74 (28)	95 (36)	16 (6)	24
415	GARZA LITTLE ELM RESERVO	34 (13)	13 (5)	16 (6)	34 (13)	55 (21)	21 (7)	17
416	[illegible] LAKE	76 (29)	61 (23)	55 (21)	55 (21)	94 (32)	92 (34)	42
417	[illegible] LAKE	16 (6)	26 (9)	8 (3)	24 (9)	72 (27)	11 (4)	13
418	LAKE OF THE PINES	54 (20)	76 (28)	66 (25)	39 (15)	17 (6)	46 (17)	24
419	LAVON RESERVOIR	21 (8)	29 (11)	3 (1)	84 (32)	100 (38)	21 (7)	25
420	LIVINGSTON LAKE	3 (1)	3 (1)	39 (15)	26 (10)	17 (6)	3 (1)	9
421	LYNDON B JOHNSON LAKE	39 (14)	11 (4)	53 (20)	66 (25)	38 (14)	30 (10)	23
422	[illegible] LAKE	66 (25)	8 (3)	58 (34)	37 (14)	17 (6)	100 (38)	34
423	LAKE [illegible]	92 (35)	91 (33)	71 (27)	95 (36)	38 (14)	63 (23)	44
424	PALESTINE LAKE	74 (28)	32 (12)	63 (24)	53 (20)	49 (17)	51 (19)	34
425	[illegible] RESERVOIR	74 (28)	91 (33)	84 (32)	58 (22)	17 (6)	63 (23)	34
426	SAN ANGELO RESERVOIR	13 (5)	45 (17)	8 (3)	8 (3)	88 (33)	46 (17)	20
427	SAN [illegible] RESERVOIR	58 (22)	39 (15)	68 (26)	76 (29)	17 (6)	63 (23)	32
428	E O SPENCE RESERVOIR	58 (22)	63 (31)	45 (17)	58 (22)	17 (6)	76 (28)	32

PERCENT OF LAKES WITH HIGHER VALUES NUMBER OF LAKES WITH HIGHER VALUES

LAKE ORDER	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	SUM- MEAN SEC	MEAN CHLOPH	25- MEAN 30	MEDIAN DISS ORTHO P	PAGES NO
429	SUMERVILLE LAP_	29 = 110	55 = 211	24 = 94	3 = 11	67 = 254	38 = 181	264
430	STAMFORD LAKE	19 = 73	47 = 177	5 = 2	16 = 71	62 = 233	35 = 144	256
431	STELLAMARE HOLLOW RESER	89 = 333	37 = 140	67 = 310	42 = 164	17 = 61	51 = 149	372
432	TAMARONE LAKE	32 = 123	78 = 284	37 = 144	21 = 83	63 = 244	38 = 181	253
433	TEARPAWN LAKE	11 = 41	51 = 199	13 = 51	16 = 61	72 = 277	13 = 51	176
434	TEXOMA LAKE	39 = 144	34 = 133	61 = 234	46 = 177	17 = 61	21 = 71	217
435	THAMES LAKE	68 = 259	21 = 71	92 = 354	82 = 313	17 = 61	84 = 317	384
436	THOMSON	0 = 0	61 = 229	11 = 41	5 = 21	92 = 354	0 = 0	369
437	TWIN WATERS RESERVOIR	59 = 229	21 = 71	58 = 223	61 = 233	44 = 171	63 = 251	311
438	WHITE HOUSE RESERVOIR	84 = 329	61 = 227	76 = 294	89 = 344	17 = 61	63 = 251	348
439	WHITNEY LAKE	63 = 246	51 = 199	78 = 301	71 = 273	17 = 61	78 = 299	357

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	LYNDON B JOHNSON LAKE	[redacted]
[redacted]	[redacted]	TEXOMA LAKE	[redacted]
[redacted]	[redacted]	SOMERVILLE LAKE	[redacted]
[redacted]	[redacted]	SAN ANGELO RESERVOIR	[redacted]
[redacted]	[redacted]	TOMBIGBEE LAKE	[redacted]
[redacted]	[redacted]	BAYOU LITTLE BLUE RESERVOIR	[redacted]
[redacted]	[redacted]	TEXOMA	[redacted]
[redacted]	[redacted]	BRANCH LAKE	[redacted]
[redacted]	[redacted]	CORPUS CHRISTI LAKE	[redacted]
[redacted]	[redacted]	HOUSTON LAKE	[redacted]
[redacted]	[redacted]	LOCHINVER LAKE	[redacted]

[redacted]

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

[illegible]
31 51 58.1 097 22 14.8 3
[illegible]ITNEY LAKE
[illegible]S TEXAS

[illegible]

[illegible]ERPALES Z_111242
3846 FEET [illegible] CLASS 00

DATE	TIME	DEPTH	00010 WATER TEMP	00300 DO	01077 TRANSP SECCHI	00094 CNDUCTVY FIELD	00400 PH	00410 T ALK CACO3	00418 [illegible] TOTAL	00625 TOT KJEL N	00630 NO3N&O2 N-TOTAL	00671 PHOS-DIS ORTHO
[illegible]												
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ID	DAY	FEET	CENT	MG/L	INCHES	MICROMHO	SU	MG/L	MG/L	MG/L	MG/L	MG/L P
[illegible]	[illegible] 30	[illegible]	12.4		106	1560	6.22	135	0.836	0.480	0.196	0.026
	[illegible] 30	[illegible]	12.7	10.8		1525	6.29	134	0.836	0.480	0.095	0.585
	[illegible] 30	0623	12.5	9.9		1490	6.25	135	0.833	0.480	0.068	0.084
	[illegible] 30	0650	11.6	12.9		1480	6.29	134	0.846	0.480	0.068	0.075
	[illegible] 30	0670	11.8	9.5		1580	6.15	136	0.842	0.480	0.068	0.086
	[illegible] 30	0642	10.5	8.8		1470	6.05	136	0.870	0.480	0.060	0.087
[illegible]	25 08	0800	22.1		105	1910	6.88	125	0.856	0.560	0.070	0.080
	25 08	0805	22.2	7.2		1480	6.88	125	0.838	0.480	0.060	0.086
	25 08	0822	21.6	6.2		1485	7.48	125	0.858	0.480	0.060	0.087
	25 08	0838	21.3	5.8		1785	7.65	125	0.870	0.580	0.110	0.086
	25 08	0848	20.5	2.8		1783	7.48	125	0.878	0.580	0.298	0.097
	25 08	0857	20.1	1.4		1674	7.48	125	0.868	0.580	0.268	0.411
[illegible]	25 08	0808	27.5	6.6	72	2284	6.38					
	25 08	0815	27.0	6.4		2195	6.15					
	25 08	0838	26.4	5.8		2144	6.08					
	25 08	0845	26.4	6.4		2261	7.71					
	25 08	0900	24.2	0.8		2252	7.71					
	25 08	0914	24.7	0.8		1978	7.46					
[illegible]	11 08	0800	22.8	7.4	45	1956	7.45	134	0.898	0.780	0.038	0.309
	11 08	0805	21.4	7.2		1955	7.94	136	0.998	0.680	0.038	0.086
	11 08	0815	21.4	7.4		1988	7.91	137	0.878	0.680	0.040	0.811
	11 08	0848	21.3	7.6		1978	7.98	137	0.896	0.780	0.038	0.084
	11 08	0905	21.4	5.4		1966	7.65	136	0.256	0.480	0.040	0.810
	11 08	0914	21.4	2.6		2044	7.29	111	0.298	0.780	0.038	0.815

[illegible]

[illegible]

[illegible]
[illegible]
[illegible]
[illegible] TEXAS

[illegible]

[illegible]
[illegible] FEET [illegible] CLASS 06

DATE FROM TO	TIME OF DAY	DEPTH FEET	BOARD MASS-CUT [illegible]	DEPTH CHLORPHYL a [illegible]	BREEDING INCUT LI REMARKS [illegible]
[illegible]	13 30	[illegible]	[illegible]	1.7	
	13 30	[illegible]	[illegible]		
	13 30	[illegible]	[illegible]		
	13 30	[illegible]	[illegible]		
	13 30	[illegible]	[illegible]		
	13 30	[illegible]	[illegible]		
[illegible]	15 00	[illegible]	[illegible]	1.6	
	15 00	[illegible]	[illegible]		
	15 00	[illegible]	[illegible]		
	15 00	[illegible]	[illegible]		
	15 00	[illegible]	[illegible]		
	15 00	[illegible]	[illegible]		
[illegible]	15 00	[illegible]		11.9	
[illegible]	11 00	[illegible]	[illegible]	4.8	
	11 00	[illegible]	[illegible]		
	11 00	[illegible]	[illegible]		
	11 00	[illegible]	[illegible]		
	11 00	[illegible]	[illegible]		
	11 30	[illegible]	[illegible]		

P.S.C.

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	14	38	0000	0.420	2.8
	14	38	0005	0.419	
	14	38	0020	0.421	
	14	38	0040	0.425	
	14	38	0046	0.425	
[illegible]	15	25	0000	0.413	2.9
	15	25	0005	0.413	
	15	25	0015	0.413	
	15	25	0030	0.413	
	15	25	0040	0.416	
	15	25	0049	0.423	
[illegible]	14	25	0006		14.9
[illegible]	10	38	0000	0.434	7.2
	10	38	0005	0.433	
	10	38	0015	0.432	
	10	39	0035	0.433	
	11	38	0055	0.445	
	10	39	0073	0.445	

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

[illegible]

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] MEAS-TOT [illegible]	[illegible] CHLORIDE, [illegible]	[illegible] [illegible] [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	15 10 0000		4,822	1.9	
	15 12 0005		4,822		
	15 18 0020		4,821		
	15 18 0045		4,822		
	15 19 0072		4,833		
[illegible]	15 45 0000		4,817	3.4	
	15 45 0005		4,817		
	15 45 0015		4,816		
	15 45 0035		4,821		
	15 45 0055		4,825		
	15 45 0066		4,826		
[illegible]	11 55 0000			2.0	
	11 55 0016				5.0
	11 55 0029				1.0
[illegible]	10 05 0000		4,841	5.4	
	10 05 0005		4,841		
	10 05 0015		4,840		
	10 05 0030		4,834		
	10 05 0045		4,841		
	10 05 0066		4,855		

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]
[illegible]

[illegible]

APPENDIX E

TRIBUTARY DATA

[illegible]

[illegible]
[illegible]
[illegible]

STORET RETRIEVAL DATE [illegible]

[illegible]
32 11 45.0 097 36 25.0 4
[illegible]
4 1 [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO3+NO2 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-TOT (MG/L P) MG/L	00665 PHOS-TOT MG/L P
[illegible]	11 45		0.017	0.700	0.015	0.016	0.017
[illegible]	11 55		0.044	0.400	0.026	0.035	0.025
[illegible]	11 45		0.136	0.400	0.026	0.030	0.038
[illegible]	15 15		0.134	0.500	0.040	0.030	0.018
[illegible]	10 20		0.375	0.560	0.026	0.007	0.040
[illegible]	09 30		0.020	0.700	0.030	0.010	0.026
[illegible]	13 30		0.030	0.750	0.005	0.012	0.026
[illegible]	12 13		0.025	0.550	0.035	0.005	0.0190
[illegible]	15 47		0.315	7.400	0.040	0.040	0.040
[illegible]	13 45		0.540	0.550	0.025	0.015	0.040

< VALUE KNOWN TO BE
LESS THAN INDICATED

[illegible]

[illegible]
[illegible]
[illegible]

[illegible]

[illegible]
32 48 28.4 097 29 48.8 4
STEELE CREEK
[illegible]
T.24S.-R.27E. [illegible]
[illegible]
[illegible]
0800 FEET DEPTH CLASS IV

DATE	TIME	DEPTH OF WATER TOTAL	BARIUM, DISSOLVED (UG/L AS BA)	BARIUM, TOTAL (UG/L AS BA)	BERYLLIUM, DISSOLVED (UG/L AS BE)	BERYLLIUM, TOTAL (UG/L AS BE)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* VALUE KNOWN TO BE LESS THAN INDICATED

[illegible]

[illegible] RETRIEVAL DATE [illegible]

[illegible]
32 02 58.0 097 33 12.0 +
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] [illegible] MG/KG	[illegible] [illegible] MG/KG	[illegible] [illegible] MG/KG	[illegible] [illegible] MG/KG	[illegible] [illegible] MG/KG
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]
[illegible]

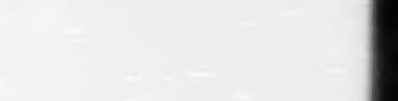
[illegible] RETRIEVAL DATE: [illegible]

[illegible]
32 12 12.0 097 33 [illegible]
[illegible]
[illegible] T.O [illegible]
[illegible]
[illegible]
[illegible]
[illegible] 2111234
[illegible] FEET [illegible] CLASS [illegible]

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] MG/L	[illegible] DIS. MG/L	[illegible] TOTAL %	[illegible] DISS. [illegible] MG/L	[illegible] DISS. [illegible] MG/L
74/09/07	12	25	0.046	0.488	0.028	0.005<	0.005<
74/10/12	11	28	0.352	0.488	0.020	0.005<	0.010<
74/11/19	10	00	0.384	0.386	0.015	0.005<	0.010<
75/01/27			0.266	0.334	0.032	0.00[illegible]	0.010<
75/02/[illegible]	14	28	0.254	1.260	0.046	0.00[illegible]	0.010<
75/03/25	09	30	0.360	0.258	0.046	0.005	0.010<
75/04/22	13	01	0.260	0.488	0.015	0.005<	0.046
75/04/29	12	00	0.270	0.256	0.046	0.005<	0.010<
75/06/18	08	01	0.240	1.198	0.056	0.030	0.110
75/07/22	14	07	0.346	0.488	0.045	0.005<	0.110

* [illegible] [illegible] TO BE
LESS THAN [illegible]

[illegible]



DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	TOT KJEL	NITRA	AMER-ICA	AMER-ICA
TO	DAY	FEET	MG/L	MG/L	TOTAL MG/L	DRIED MG/L P	MG/L P
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							

[redacted]